UCSD MicroGrid:
A Scientific Tool for Modelling Computational Grids

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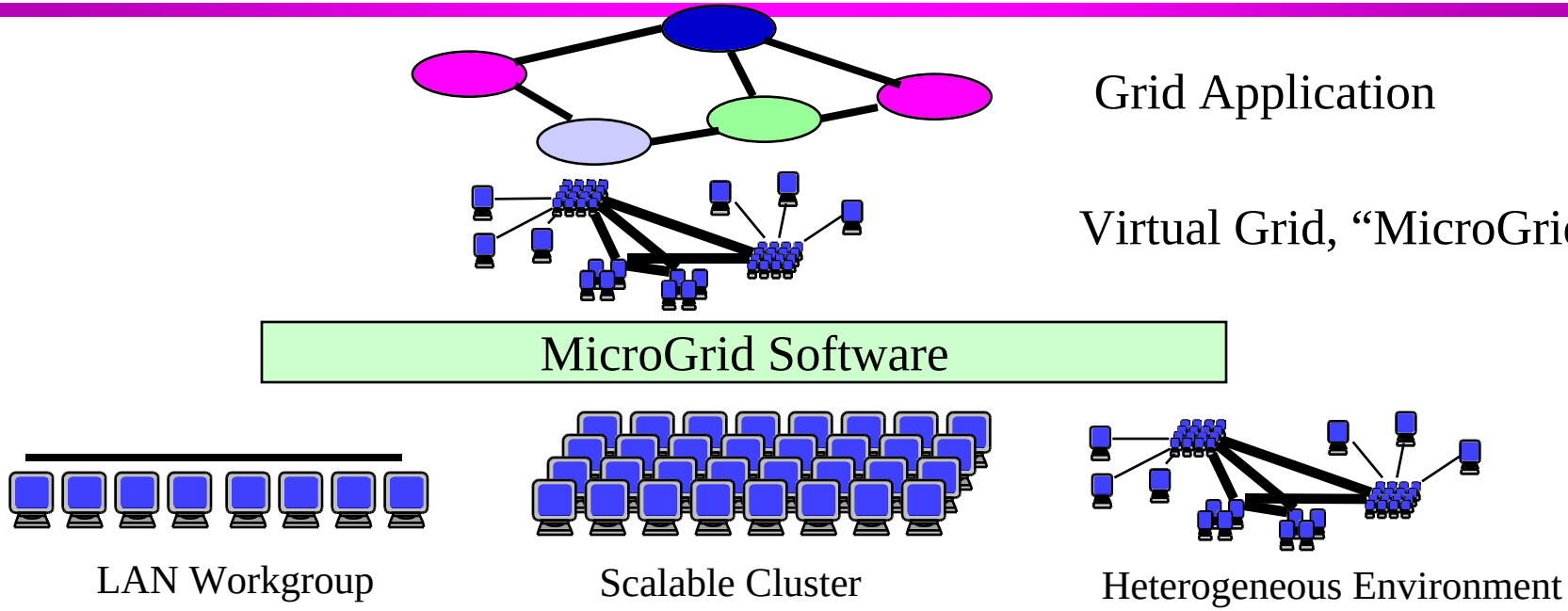
Outline

- Motivation: Need for Modelling Tools
- Requirements for a MicroGrid
- MicroGrid Design
- Validation
- Status and Future Plans

What is a MicroGrid?



- Support emulation and experimentation with grids on a variety of virtual resources. Easy, flexible experimentation with grid applications, resource management, and system services.
- ***Scientific tool for modeling Computational Grids***
- Complement MacroGrid experiments; make best use of available experimental resources

Background: Challenges in the Internet

- Explosive Growth and Complexity of the Internet
  - » growing at an exponential rate (100M+ in 1999)
  - » the largest, most complex system on the earth (billions of elements)
- Growing importance of the Internet – critical for
  - » Business: e-commerce, internal communication and infrastructure
  - » Government: dissemination/collection of information (IRS, Social security), internal IT function, etc.
  - » Health care: information management, remote monitoring, logistics and supply
  - » Management and control of critical infrastructures: power/water/sewage/weather/emergency
  - » global communication: massive quantities of email, fax, web pages
- We have little capability to model, experiment with, rationally plan, or design the evolution and reliability of the Internet.

Challenges for Computational Grids

- Grids (the Next Generation Internet) are significantly more complex than the existing internet
  - » Larger scale
  - » Wide variety of performance demands (4 to 6 orders of magnitude)
  - » Tightly couple communication, computing, and storage resources
- Grids are complex non-linear dynamic systems
- Competitive Resource sharing can lead to
  - » Unpredictable dynamic behavior
  - » Unstable dynamic behavior
  - » Denial of service and Failure

- => Ideally, Grids should be reliable and robust

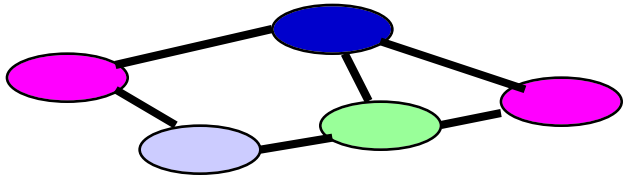
Applications of Modelling Tools (Needs)

- Predictive Modelling
  - » Operations Planning, Expansion Planning (system level performance, reliability, scalability)
  - » Applications Architecture/Design (performance, reliability, scalability)
- Post-Mortem Analysis
  - » Diagnosis/Understanding of Behavior (what happened?)
- Modelling for Design
  - » Network Protocols (beyond TCP?)
  - » Resource Protocols (ensuring stability and performance)
  - » Failure Protocols (graceful degradation)
- Others?

MicroGrid Requirements

- Support a Grid software environment (Globus)
- High Fidelity emulation of virtual resources
- Observable, Repeatable Behavior
- Large experiments (1K, 1M, 100M nodes?)
- Enable experiments on “Typical” environments

MicroGrid Architecture & Status



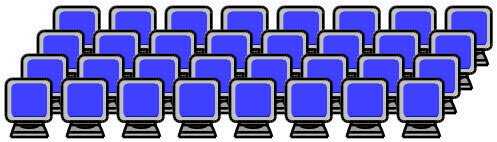
Grid Application

Virtualization Modules

Information Services	Resource Access	Basic Resources (computing, communication)	Low-level Grid Services

- Interception, Virtualization, Emulation — Working
- Global Virtual Time — Static -> Dynamic
- Robust, repeatable — Runs possible
- Scalable — Distributed runs, network simulation limits
- Validated — Solid Progress

Using a MicroGrid



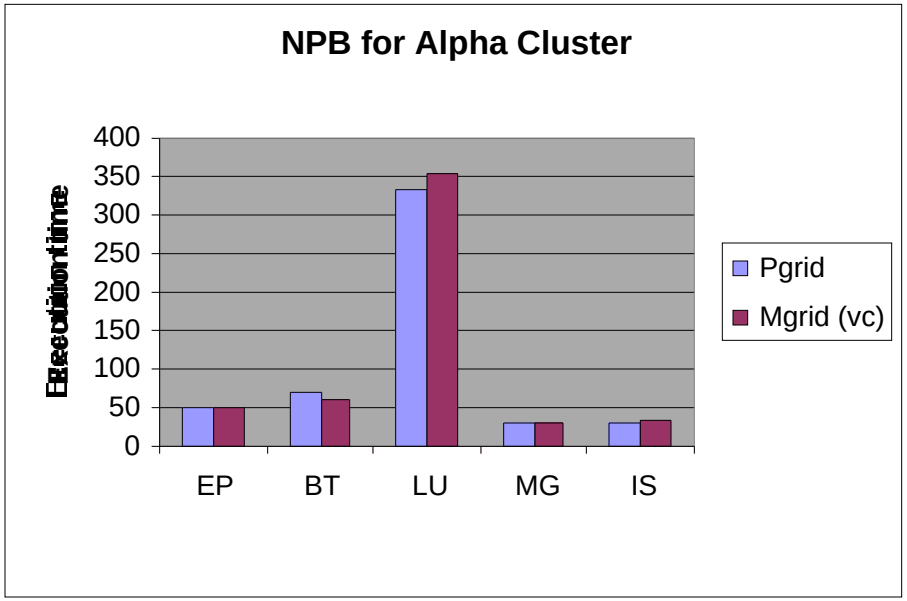
- Find some physical resources
- Configure a Virtual Grid
- Submit a Globus Job to it
- Observe Execution (which occurs in virtual time)
- DeConfigure the Virtual Grid

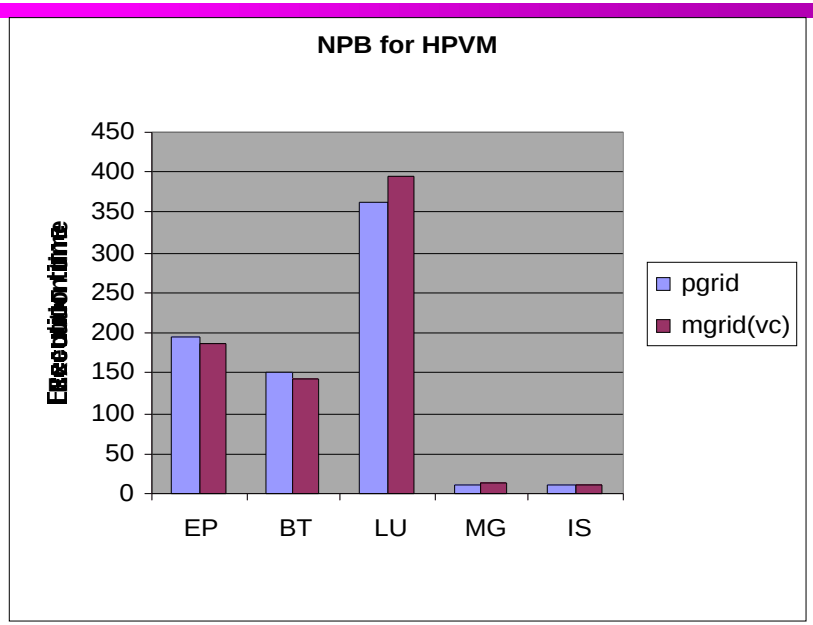
Progress

- Virtual Grid MDS entries
  - » definition, simple config tools, enter/remove
- Virtualization of Processors/Communication
  - » virtual name mapping in MDS, process creation and network socket virtualization
- Emulation of Grid Resources
  - » processing (proportional share scheduler) and memory limits
  - » network simulation with NS/NSE
- + Integrated together

- System runs a variety of Globus and MPICH-G programs!
- All runs on Alpha/Linux with IP networks

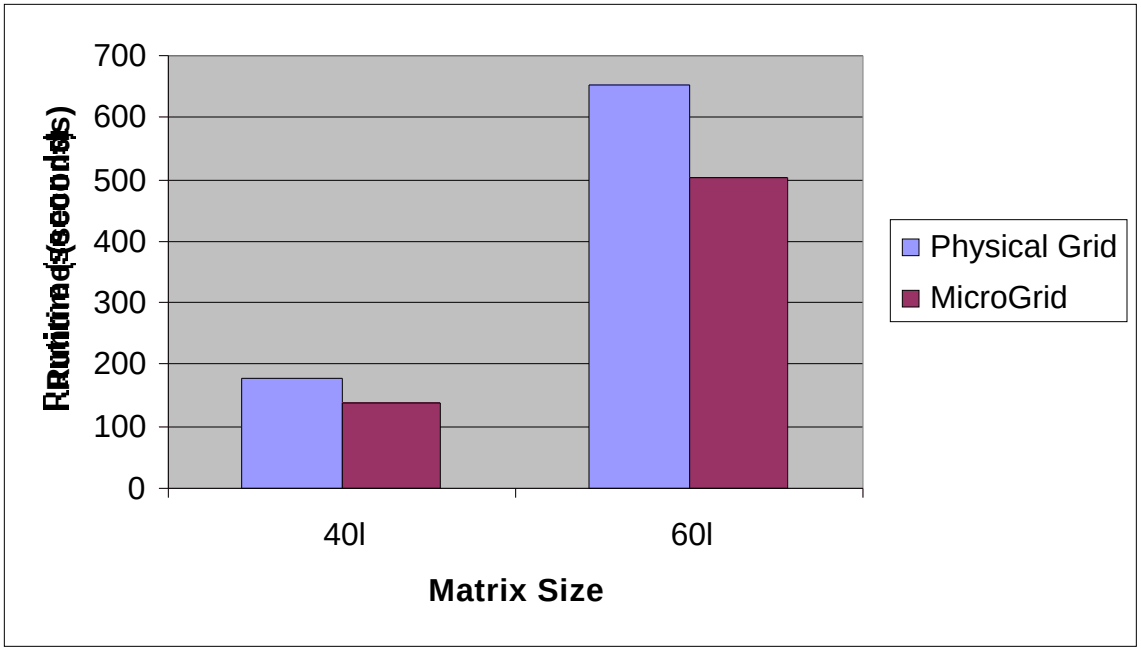
Total RT Validation on NPB





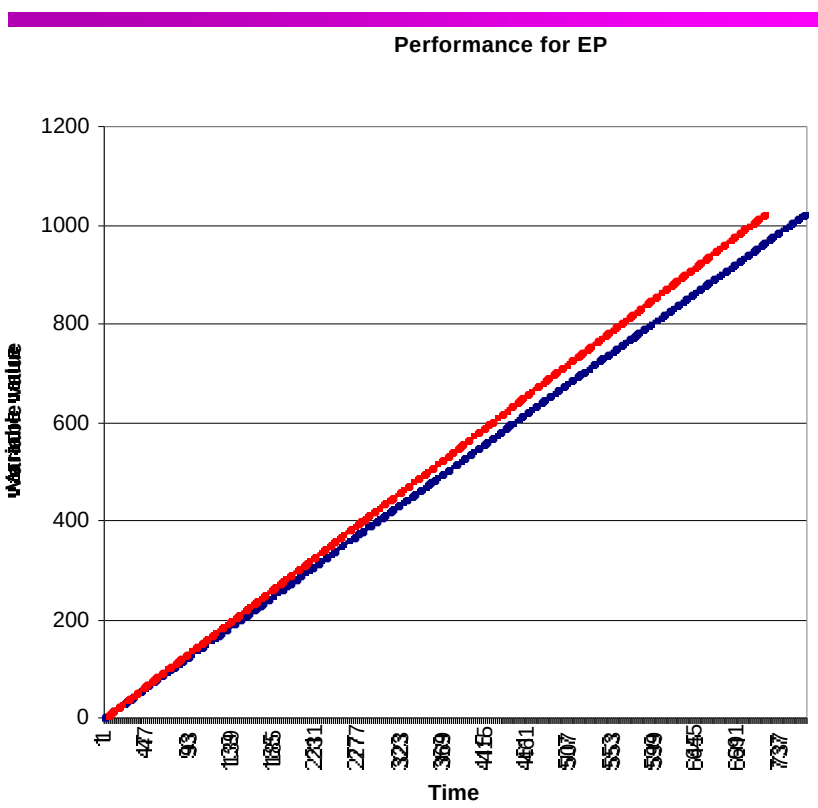
- Comparison to published cluster NPB results
  - » Set parameters based on known published relative resource performance -- processor and network performance
  - » Avalon cluster (Alpha's + 100Mbit ethernet)
  - » HPVM cluster (ours)
- Overall execution time matching within 2-4%

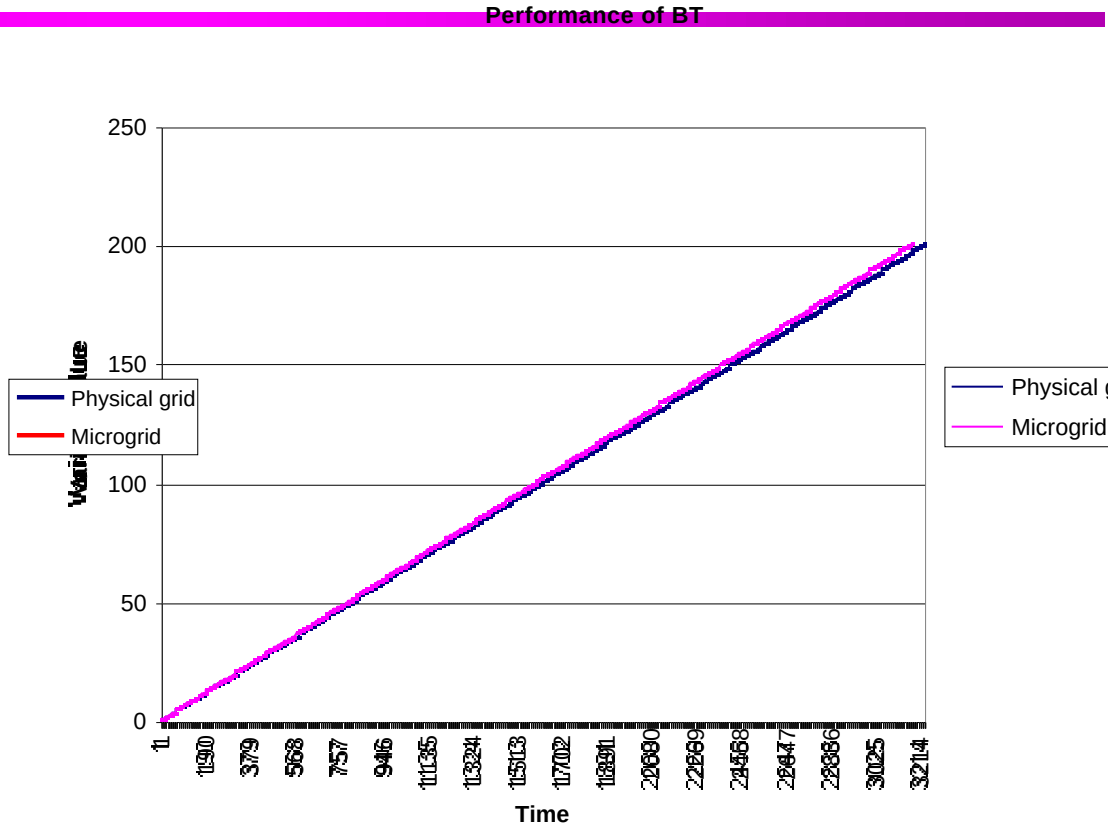
Total RT Validation (Cactus)



- Cactus PDE Solver Framework, more complex application
- WaveToy program running over MPICH-G
- Various Matrix sizes against an Alpha/100Mbit cluster model

Continuous Registration on NPB





- Use Application + Autopilot tools, run in MicroGrid environment
- Compare traces to runs with App + Autopilot in real Grid environment
- Detailed registration within 5%, could be improved.

Status and Short Term Plans

- Basic emulation of Globus Grid Environment
- Validation on a range of programs
- Now running on Alpha Linux cluster, with 100Mbit ethernet
- Next goals:
  - » Increase robustness, support others to use
  - » Implement dynamic virtual time
- Continued Extension/Improvement
  - » Network simulation scaling
  - » Improve range of network models and configurations
  - » Improve virtualization (intercept known other information sources)

Longer Term Plans

- Fundamental Research Issues in Scalable Network Simulation
  - » Goals of 1M to 100M node simulations
- Fundamental Research in Application, Network Traffic Modeling
- Fundamental Research Challenges in Experimental Methodology for Extrapolation and Scaleup
- Fundamental Grid Software Challenges

Related Research

- Network Traffic Modeling
  - » Network Weather Service [Wolski98]
  - » Bricks/Ninf [HPDC99,HPC98]
  - » Internet Traffic Modeling [Willinger95, Crovella97]
- Network Simulation / General Discrete Event Simulation
  - » VINT/NS [Bajaj, Estrin, et. al. 1999], PDNS [Fujimoto99]
  - » SSF [Nicol, et al. 1999]
  - » MPISim [Bagrodia98]
- Performance Modelling tools for Parallel Machines [Numerous]

Summary

- Scalable, high fidelity modelling tools are a critical need for the Internet and Grid communities
- UCSD MicroGrid goal is scalable, high fidelity emulation/simulation environment for Computational Grids
  - » Globus environment based
  - » Virtualization of resource environment
  - » Open architecture for node and network modelling
- Solid first steps in virtualization and validation

- For more information see **`http://www-csag.ucsd.edu/`**

MicroGrid Team

- Andrew Chien (PI)
- Graduate Students:
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  - Dr. Hyo Jung Song (Postdoc)
  - Dr. Kenjiro Taura (U Tokyo Professor)
  - Dennis Jakobsen (MS)